XVI. *New Experiments on the Ocular Spectra of Light and Colours. By* Robert Waring Darwin, *M. D.; communicated by* Erasmus Darwin, *M. D. F. R. S.*

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WHEN any one has long and attentively looked at a bright object, as at the setting sun, on closing his eyes, or removing them, an image, which resembles in form the object he was attending to, continues some time to be visible: this appearance in the eye we shall call the ocular spectrum of that object.

These ocular spectra are of four kinds: 1st, Such as are owing to a less sensibility of a defined part of the retina; or *spectra from defect of sensibility*. 2d, Such as are owing to a greater sensibility of a defined part of the retina; or *spectra from excess of sensibility*. 3d, Such as resemble their object in its colour as well as form; which may be termed *direct ocular spectra*. 4th, Such as are of a colour contrary to that of their object; which may be termed *reverse ocular spectra*.

The laws of light have been most successfully explained by the great NEWTON, and the perception of visible objects has been ably investigated by the ingenious Dr. BERKELEY and M. MALEBRANCHE; but these minute phænomena of vision have yet been thought reducible to no theory, though many philosophers have employed a considerable degree of attention upon them: among these are Dr. JURIN, at the end of Dr. SMITH's Optics; M.

ÆPINUS, in the Nov. Com. Petropol. V. 10.; M. BEGUELIN, in the Berlin Memoires, V. II. 1771; M. D'ARCY, in the Hiſtoire de l'Acad. des Scienc. 1765; M. DE LA HIRE; and, laſtly, the celebrated M. DE BUFFON, in the Memoires de l'Acad. des Scien. who has termed them accidental colours, as if ſubjected to no eſtabliſhed laws, Ac. Par. 1743. M. p. 215.

I muſt here apprize the reader, that it is very difficult for different people to give the ſame names to various ſhades of colours; whence, in the following pages, ſomething muſt be allowed if, on repeating the experiments, the colours here mentioned ſhould not accurately correſpond with his own names of them.

I. ACTIVITY OF THE RETINA IN VISION.

From the ſubſequent experiments it appears, that the retina is in an active not in a paſſive ſtate during the exiſtence of theſe ocular ſpectra; and it is thence to be concluded, that all viſion is owing to the activity of this organ.

1. Place a piece of red ſilk, about an inch in diameter, as in fig. 1. (Tab. IX.) on a ſheet of white paper, in a ſtrong light; look ſteadily upon it from about the diſtance of half a yard for a minute; then cloſing your eyelids cover them with your hands, and a green ſpectrum will be ſeen in your eyes, reſembling in form the piece of red ſilk: after ſome time, this ſpectrum will diſappear and ſhortly re-appear; and this alternately three or four times, if the experiment is well made, till at length it vaniſhes entirely.

2. Place on a ſheet of white paper a circular piece of blue ſilk, about four inches in diameter, in the ſunſhine; cover the center of this with a circular piece of yellow ſilk, about three

three inches in diameter; and the center of the yellow ſilk with a circle of pink ſilk, about two inches in diameter; and the center of the pink ſilk with a circle of green ſilk, about one inch in diameter; and the center of this with a circle of indigo, about half an inch in diameter; make a ſmall ſpeck with ink in the very center of the whole, as in fig. 2.; look ſteadily for a minute on this central ſpot, and then cloſing your eyes, and applying your hand at about an inch diſtance before them, ſo as to prevent too much or too little light from paſſing through the eyelids, you will ſee the moſt beautiful circles of colours that imagination can conceive, which are moſt reſembled by the colours occaſioned by pouring a drop or two of oil on a ſtill lake in a bright day; but theſe circular iriſes of colours are not only different from the colours of the ſilks abovementioned, but are at the ſame time perpetually changing as long as they exiſt.

3. When any one in the dark preſſes either corner of his eye with his finger, and turns his eye away from his finger, he will ſee a circle of colours like thoſe in a peacock's tail: and a ſudden flaſh of light is excited in the eye by a ſtroke on it. (Newton's Opt. Qu. 16.)

4. When any one turns round rapidly on one foot, till he becomes dizzy and falls upon the ground, the ſpectra of the ambient objects continue to preſent themſelves in rotation, or appear to librate, and he ſeems to behold them for ſome time ſtill in motion.

From all theſe experiments it appears, that the ſpectra in the eye are not owing to the mechanical impulſe of light impreſſed on the retina, nor to its chemical combination with that organ, nor to the abſorption and emiſſion of light, as is obſerved in many bodies: for in all theſe caſes the ſpectra muſt either remain uniformly, or gradually diminiſh; and neither their alternate preſence and evaneſcence as in the firſt experiment, nor the perpetual changes of their colours as in the ſecond, nor the flaſh of light or colours in the preſſed eye as in the third, nor the rotation or libration of the ſpectra as in the fourth, could exiſt.

It is not abſurd to conceive, that the retina may be ſtimulated into motion, as well as the red and white muſcles which form our limbs and veſſels; ſince it conſiſts of fibres, like thoſe, intermixed with its medullary ſubſtance. To evince this ſtructure, the retina of an ox's eye was ſuſpended in a glaſs of warm water, and forcibly torn in a few places; the edges of theſe parts appeared jagged and hairy, and did not contract, and become ſmooth like ſimple mucus, when it is diſtended till it breaks; which ſhews that it conſiſts of fibres; and this its fibrous conſtruction became ſtill more diſtinct to the ſight, by adding ſome cauſtic alkali to the water, as the adhering mucus was firſt eroded, and the hair-like fibres remained floating in the veſſel. Nor does the degree of tranſparency of the retina invalidate the evidence of its fibrous ſtructure, ſince LEEUWENHOEK has ſhewn that the cryſtalline humour itſelf conſiſts of fibres. (Arcana Naturæ, V. 1. p. 70.)

Hence it appears, that as the muſcles have larger fibres intermixed with a ſmaller quantity of nervous medulla, the organ of viſion has a greater quantity of nervous medulla intermixed with ſmaller fibres; and it is probable, that the locomotive muſcles, as well as the vaſcular ones, of microſcopic animals have much greater tenuity than theſe of the retina.

And beſides the ſimilar laws, which will be ſhewn in this Paper to govern alike the actions of the retina and of the muſcles,

muſcles, there are many other analogies which exiſt between them. They are both originally excited into action by irritations, both act nearly in the ſame quantity of time, are alike ſtrengthened or fatigued by exertion, are alike painful if excited into action when they are in an inflamed ſtate, are alike liable to paralyſis, and to the torpor of old age.

II. OF SPECTRA FROM DEFECT OF SENSIBILITY.

The retina is not ſo eaſily excited into action by leſs irritation after having been lately ſubjected to greater.

1. When any one paſſes from the bright daylight into a darkened room, the iriſes of his eyes expand themſelves to their utmoſt extent in a few ſeconds of time; but it is very long before the optic nerve, after having been ſtimulated by the greater light of the day, becomes ſenſible of the leſs degree of it in the room; and, if the room is not too obſcure, the iriſes will again contract themſelves in ſome degree, as the ſenſibility of the retina returns.

2. Place about half an inch ſquare of white paper on a black hat, and looking ſteadily on the center of it for a minute, remove your eyes to a ſheet of white paper; and after a ſecond or two a dark ſquare will be ſeen on the white paper, which will continue ſome time. A ſimilar dark ſquare will be ſeen in the cloſed eye, if light be admitted through the eye-lids.

So after looking at any luminous object of a ſmall ſize, as at the ſun, for a ſhort time, ſo as not much to fatigue the eyes, this part of the retina becomes leſs ſenſible to ſmaller quantities of light; hence, when the eyes are turned on other leſs luminous parts of the ſky, a dark ſpot is ſeen reſembling the

the ſhape of the ſun, or other luminous object which we laſt beheld. This is the ſource of one kind of the dark-coloured *muſcæ volitantes*. If this dark ſpot lies above the center of the eye, we turn our eyes that way, expecting to bring it into the center of the eye, that we may view it more diſtinctly; and in this caſe the dark ſpectrum ſeems to move upwards. If the dark ſpectrum is found beneath the center of the eye, we purſue it from the ſame motive, and it ſeems to move downwards. This has given riſe to various conjectures of ſomething floating in the aqueous humours of the eyes; but whoever, in attending to theſe ſpots, keeps his eyes unmoved by looking ſteadily at the corner of a cloud, at the ſame time that he obſerves the dark ſpectra, will be thoroughly convinced, that they have no motion but what is given to them by the movement of our eyes in purſuit of them. Sometimes the form of the ſpectrum, when it has been received from a circular luminous body, will become oblong; and ſometimes it will be divided into two circular ſpectra, which is owing to our changing the angle made by the two optic axiſes, according to the diſtance of the clouds or other bodies to which the ſpectrum is ſuppoſed to be contiguous. The apparent ſize of it will alſo be variable according to its ſuppoſed diſtance; but when ſuch a ſpectrum is received with only one eye, the other being covered, its form and number are invariable.

As theſe ſpectra are more eaſily obſervable when our eyes are a little weakened by fatigue, it has frequently happened, that people of delicate conſtitutions have been much alarmed at them, fearing a beginning decay of their ſight, and have thence fallen into the hands of ignorant oculiſts; but I believe they never are a prelude to any other diſeaſe of the eye, and that it is from habit alone, and our want of attention to them, that we do not ſee them on all objects every hour of our lives. But as the nerves of very weak people loſe their ſenſibility, in the ſame manner as their muſcles loſe their activity, by a ſmall time of exertion, it frequently happens, that ſick people in the extreme debility of fevers are perpetually employed in picking ſomething from the bed-cloaths, occaſioned by their miſtaking the appearance of theſe *muſcæ volitantes* in their eyes. BENVENUTO CELINI, an Italian artiſt, a man of ſtrong abilities, relates, that having paſſed the whole night on a diſtant mountain with ſome companions and a conjurer, and performed many ceremonies to raiſe the devil, on their return in the morning to Rome, and looking up when the ſun began to riſe, they ſaw numerous devils run on the tops of the houſes, as they paſſed along; ſo much were the ſpectra of their weakened eyes magnified by fear, and made ſubſervient to the purpoſes of fraud or ſuperſtition. (Life of BEN. CELINI.)

3. Place a ſquare inch of white paper on a large piece of ſtraw-coloured ſilk; look ſteadily ſome time on the white paper, and then move the center of your eyes on the ſilk, and a ſpectrum of the form of the paper will appear on the ſilk, of a deeper yellow than the other part of it: for the central part of the retina, having been ſome time expoſed to the ſtimulus of a greater quantity of white light, is become leſs ſenſible to a ſmaller quantity of it, and therefore ſees only the yellow rays in that part of the ſtraw-coloured ſilk.

Facts ſimilar to theſe are obſervable in other parts of our ſyſtem: thus, if one hand be made warm, and the other expoſed to the cold, and then both of them immerſed in ſubtepid water, the water is perceived warm to one hand, and cold to the other; and we are not able to hear weak ſounds for ſome time after we have been expoſed to loud ones; and we feel a chillineſs

chillineſs on coming into an atmoſphere of temperate warmth, after having been ſome time confined in a very warm room: and hence the ſtomach, and other organs of digeſtion, of thoſe who have been habituated to the greater ſtimulus of ſpirituous liquor, are not excited into their due action by the leſs ſtimulus of common food alone; of which the immediate conſequence is indigeſtion and hypochondriaciſm.

III. OF SPECTRA FROM EXCESS OF SENSIBILITY.

The retina is more eaſily excited into action by greater irritation after having been lately ſubjected to leſs.

1. If the eyes are cloſed, and covered perfectly with a hat, for a minute or two, in a bright day; on removing the hat a red or crimſon light is ſeen through the eye-lids. In this experiment the retina, after being ſome time kept in the dark, becomes ſo ſenſible to a ſmall quantity of light, as to perceive diſtinctly the greater quantity of red rays than of others which paſs through the eye-lids. A ſimilar coloured light is ſeen to paſs through the edges of the fingers, when the open hand is oppoſed to the flame of a candle.

2. If you look for ſome minutes ſteadily on a window in the beginning of the evening twilight, or in a dark day, and then move your eyes a little, ſo that thoſe parts of the retina, on which the dark frame-work of the window was delineated, may now fall on the glaſs part of it, many luminous lines, repreſenting the frame-work, will appear to lie acroſs the glaſs panes: for thoſe parts of the retina, which were before leaſt ſtimulated by the dark frame-work, are now more ſenſible to

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light than the other parts of the retina which were expofed to the more luminous parts of the window.

3. Make with ink on white paper a very black fpot, about half an inch in diameter, with a tail about an inch in length, fo as to reprefent a tadpole; look fteadily for a minute on this fpot, and, on moving the eye a little, the figure of the tadpole will be feen on the white part of the paper, which figure of the tadpole will appear whiter or more luminous than the other parts of the white paper; for the part of the retina on which the tadpole was delineated, is now more fenfible to light than the other parts of it, which were expofed to the white paper. This experiment is mentioned by Dr. Irwin, but is not by him afcribed to the true caufe, namely, the greater fenfibility of that part of the retina which has been expofed to the black fpot, than of the other parts which had received the white field of paper, which is put beyond a doubt by the next experiment.

4. On clofing the eyes after viewing the black fpot on the white paper, as in the foregoing experiment, a red fpot is feen of the form of the black fpot: for that part of the retina, on which the black fpot was delineated, being now more fenfible to light than the other parts of it, which were expofed to the white paper, is capable of perceiving the red rays which penetrate the eyelids. If this experiment be made by the light of a tallow candle, the fpot will be yellow inftead of red; for tallow candles abound much with yellow light, which paffes in greater quantity and force through the eyelids than blue light; hence the difficulty of diftinguifhing blue and green by this kind of candle light. The colour of the fpectrum may poffibly vary in the day light, according to the different colour of the meridian or the morning or evening light.

M. BEGUELIN, in the Berlin Memoires, V. II. 1771, obſerves, that, when he held a book ſo that the ſun ſhone upon his half-cloſed eyelids, the black letters, which he had long inſpected, became red, which muſt have been thus occaſioned. Thoſe parts of the retina which had received for ſome time the black letters, were ſo much more ſenſible than thoſe parts which had been oppoſed to the white paper, that to the former the red light, which paſſed through the eyelids, was perceptible. There is a ſimilar ſtory told, I think, in M. DE VOLTAIRE'S Hiſtorical Works, of a Duke of Tuſcany, who was playing at dice with the general of a foreign army, and, believing he ſaw bloody ſpots upon the dice, portended dreadful events, and retired in confuſion. The obſerver, after looking for a minute on the black ſpots of a die, and careleſſly cloſing his eyes, on a bright day, would ſee the image of a die with red ſpots upon it, as above explained.

5. On emerging from a dark cavern, where we have long continued, the light of a bright day becomes intolerable to the eye for a conſiderable time, owing to the exceſs of ſenſibility exiſting in the eye, after having been long expoſed to little or no ſtimulus. This occaſions us immediately to contract the iris to its ſmalleſt aperture, which becomes again gradually dilated, as the retina becomes accuſtomed to the greater ſtimulus of the daylight.

The twinkling of a bright ſtar, or of a diſtant candle in the night, is perhaps owing to the ſame cauſe. While we continue to look upon theſe luminous objects, their central parts gradually appear paler, owing to the decreaſing ſenſibility of the part of the retina expoſed to their light; whilſt, at the ſame time, by the unſteadineſs of the eye, the edges of them are perpetually falling on parts of the retina that were juſt before

before expofed to the darknefs of the night, and therefore tenfold more fenfible to light than the part on which the ftar or candle had been for fome time delineated. This pains the eye in a fimilar manner as when we come fuddenly from a dark room into bright daylight, and gives the appearance of bright fcintillations. Hence the ftars twinkle moft when the night is darkeft, and do not twinkle through telefcopes, as obferved by MUSSCHENBROECK; and it will afterwards be feen why this twinkling is fometimes of different colours when the object is very bright, as Mr. MELVILL obferved in looking at Sirius. For the opinions of others on this fubject, fee Dr. PRIESTLEY's valuable Hiftory of Light and Colours, p. 494.

Many facts obfervable in the animal fyftem are fimilar to thefe; as the hot glow occafioned by the ufual warmth of the air, or our cloaths, on coming out of a cold bath; the pain of the fingers on approaching the fire after having handled fnow; and the inflamed heels from walking in fnow. Hence thofe who have been expofed to much cold have died on being brought to a fire, or their limbs have become fo much inflamed as to mortify. Hence much food or wine given fuddenly to thofe who have almoft perifhed by hunger has deftroyed them; for all the organs of the famifhed body are now become fo much more irritable to the ftimulus of food and wine, which they have long been deprived of, that inflammation is excited, which terminates in gangrene or fever.

IV. OF DIRECT OCULAR SPECTRA.

A quantity of ſtimulus ſomewhat greater than natural excites the retina into ſpaſmodic action, which ceaſes in a few ſeconds.

A certain duration and energy of the ſtimulus of light and colours excites the perfect action of the retina in viſion; for very quick motions are imperceptible to us, as well as very ſlow ones, as the whirling of a top, or the ſhadow on a ſun-dial. So perfect darkneſs does not affect the eye at all; and exceſs of light produces pain, not viſion.

1. When a fire-coal is whirled round in the dark, a lucid circle remains a conſiderable time in the eye; and that with ſo much vivacity of light, that it is miſtaken for a continuance of the irritation of the object. In the ſame manner, when a fiery meteor ſhoots acroſs the night, it appears to leave a long lucid train behind it, part of which, and perhaps ſometimes the whole, is owing to the continuance of the action of the retina after having been thus vividly excited. This is beautifully illuſtrated by the following experiment: fix a paper ſail, three or four inches in diameter, and made like that of a ſmoke jack, in a tube of paſteboard; on looking through the tube at a diſtant proſpect, ſome disjointed parts of it will be ſeen through the narrow intervals between the ſails; but as the fly begins to revolve, theſe intervals appear larger; and when it revolves quicker, the whole proſpect is ſeen quite as diſtinct as if nothing intervened, though leſs luminous.

2. Look through a dark tube, about half a yard long, at the area of a yellow circle of half an inch diameter, lying upon a blue area of double that diameter, for half a minute; and

and on closing your eyes the colours of the spectrum will appear similar to the two areas, as in fig. 3.; but if the eye is kept too long upon them, the colours of the spectrum will be the reverse of those upon the paper, that is, the internal circle will become blue, and the external area yellow; hence some attention is required in making this experiment.

3. Place the bright flame of a spermaceti candle before a black object in the night; look steadily at it for a short time, till it is observed to become somewhat paler; and on closing the eyes, and covering them carefully, but not so as to compress them, the image of the blazing candle will continue distinctly to be visible.

4. Look steadily, for a short time, at a window in a dark day, as in Exp. 2. S. III. and then closing your eyes, and covering them with your hands, an exact delineation of the window remains for some time visible in the eye. This experiment requires a little practice to make it succeed well; since, if the eyes are fatigued by looking too long on the window, or the day be too bright, the luminous parts of the window will appear dark in the spectrum, and the dark parts of the frame-work will appear luminous, as in Exp. 2. S. III. And it is even difficult for many, who first try this experiment, to perceive the spectrum at all; for any hurry of mind, or even too great attention to the spectrum itself, will disappoint them, till they have had a little experience in attending to such small sensations.

The spectra described in this section, termed direct ocular spectra, are produced without much fatigue of the eye; the irritation of the luminous object being soon withdrawn, or its quantity of light being not so great as to produce any degree of uneasiness in the organ of vision; which distinguishes them from

from the next clafs of ocular fpectra, which are the confe-quence of fatigue. Thefe direct fpectra are beft obferved in fuch circumftances that no light, but what comes from the object, can fall upon the eye; as in looking through a tube, of half a yard long, and an inch wide, at a yellow paper on the fide of a room, the direct fpectrum was eafily produced on clofing the eye without taking it from the tube: but if the lateral light is admitted through the eye-lids, or by throwing the fpectrum on white paper, it becomes a reverfe fpectrum, as will be explained below.

The other fenfes alfo retain for a time the impreffions that have been made upon them, or the actions they have been ex-cited into. So if a hard body is preffed upon the palm of the hand, as is practifed in tricks of legerdemain, it is not eafy to diftinguifh for a few feconds whether it remains or is removed; and taftes continue long to exift vividly in the mouth, as the fmoke of tobacco, or the tafte of gentian, after the fapid material is withdrawn.

V. *A quantity of ftimulus fomewhat greater than the laft men-tioned excites the retina into fpafmodic action, which ceafes and recurs alternately.*

1. On looking for a time on the fetting fun, fo as not greatly to fatigue the fight, a yellow fpectrum is feen when the eyes are clofed and covered, which continues for a time and then difappears, and recurs repeatedly before it intirely vanifhes. This yellow fpectrum of the fun when the eye-lids are opened becomes blue; and if it is made to fall on the green grafs, or on other coloured objects, it varies its own colou

colour by an intermixture of theirs, as will be explained in another place.

2. Place a lighted ſpermaceti candle in the night about one foot from your eye, and look ſteadily on the center of the flame, till your eye becomes much more fatigued than in S. IV. Exp. 3. ; and on cloſing your eyes a reddiſh ſpectrum will be perceived, which will ceaſe and return alternately.

The action of vomiting in like manner ceaſes, and is renewed by intervals, although the emetic drug is thrown up with the firſt effort: ſo after-pains continue ſome time after parturition; and the alternate pulſations of the heart of a viper are renewed for ſome time after it is cleared from its blood.

VI. OF REVERSE OCULAR SPECTRA.

The retina after having been excited into action by a ſtimulus ſomewhat greater than the laſt mentioned falls into oppoſite ſpaſmodic action.

The actions of every part of animal bodies may be advantageouſly compared with each other. This ſtrict analogy contributes much to the inveſtigation of truth; while thoſe looſer analogies, which compare the phænomena of animal life with thoſe of chemiſtry or mechanics, only ſerve to miſlead our enquiries.

When any of our larger muſcles have been in long or in violent action, and their antagoniſts have been at the ſame time extended, as ſoon as the action of the former ceaſes, the limb is ſtretched the contrary way for our eaſe, and a pandiculation or yawning takes place.

By the following obſervations it appears, that a ſimilar circumſtance obtains in the organ of viſion; after it has been fatigued by one kind of action, it ſpontaneouſly falls into the oppoſite kind.

1. Place a piece of coloured ſilk, about an inch in diameter, on a ſheet of white paper, about half a yard from your eyes; look ſteadily upon it for a minute; then remove your eyes upon another part of the white paper, and a ſpectrum will be ſeen of the form of the ſilk thus inſpected, but of a colour oppoſite to it. A ſpectrum nearly ſimilar will appear if the eyes are cloſed, and the eyelids ſhaded by approaching the hand near them, ſo as to permit ſome but to prevent too much light falling on them.

Red ſilk produced a green ſpectrum.
Green produced a red one.
Orange produced blue.
Blue produced orange.
Yellow produced violet.
Violet produced yellow.

That in theſe experiments the colours of the ſpectra are the reverſe of the colours which occaſioned them, may be ſeen by examining the third figure in Sir ISAAC NEWTON's Optics, L. II. p. 1. where thoſe thin laminæ of air, which reflected yellow, tranſmitted violet; thoſe which reflected red, tranſmitted a blue-green; and ſo of the reſt, agreeing with the experiments above related.

2. Theſe reverſe ſpectra are ſimilar to a colour, formed by a combination of all the primary colours except that with which the eye has been fatigued in making the experiment: thus the reverſe ſpectrum of red muſt be ſuch a green as would be produced by a combination of all the other priſmatic colours.

To

To evince this fact the following satisfactory experiment was made. The prismatic colours were laid on a circular pasteboard wheel, about four inches in diameter, in the proportions described in Dr. PRIESTLEY's History of Light and Colours, pl. 12. fig. 83. except that the red compartment was intirely left out, and the others proportionably extended so as to complete the circle. Then, as the orange is a mixture of red and yellow, and as the violet is a mixture of red and indigo, it became necessary to put yellow on the wheel instead of orange, and indigo instead of violet, that the experiment might more exactly quadrate with the theory it was designed to establish or confute; because in gaining a green spectrum from a red object, the eye is supposed to have become insensible to red light. This wheel, by means of an axis, was made to whirl like a top; and on its being put in motion, a green colour was produced, corresponding with great exactness to the reverse spectrum of red.

3. In contemplating any one of these reverse spectra in the closed and covered eye, it disappears and re-appears several times successively, till at length it intirely vanishes, like the direct spectra in sect. v.; but with this additional circumstance, that when the spectrum becomes faint or evanescent, it is instantly revived by removing the hand from before the eyelids, so as to admit more light: because then not only the fatigued part of the retina is inclined spontaneously to fall into motions of a contrary direction, but being still sensible to all other rays of light, except that with which it was lately fatigued, is by these rays at the same time stimulated into those motions which form the reverse spectrum.

From these experiments there is reason to conclude, that the fatigued part of the retina throws itself into a contrary mode of action, like oſcitation or pandiculation, as ſoon as the ſtimulus which has fatigued it is withdrawn; and that it ſtill remains ſenſible, that is, liable to be excited into action by any other colours at the ſame time, except the colour with which it has been fatigued.

VII. *The retina after having been excited into action by a ſtimulus ſomewhat greater than the laſt mentioned falls into various ſucceſſive ſpaſmodic actions.*

1. On looking at the meridian ſun as long as the eyes can well bear its brightneſs, the diſc firſt becomes pale, with a luminous creſcent, which ſeems to librate from one edge of it to the other, owing to the unſteadineſs of the eye; then the whole phaſis of the ſun becomes blue, ſurrounded with a white halo; and on cloſing the eyes, and covering them with the hands, a yellow ſpectrum is ſeen, which in a little time changes into a blue one.

M. DE LA HIRE obſerved, after looking at the bright ſun, that the impreſſion in his eye firſt aſſumed a yellow appearance, and then green, and then blue; and wiſhes to aſcribe theſe appearances to ſome affection of the nerves. (PORTERFIELD on the Eye, Vol. I. p. 343.)

2. After looking ſteadily on about an inch ſquare of pink ſilk, placed on white paper, in a bright ſunſhine, at the diſtance of a foot from my eyes, and cloſing and covering my eyelids, the ſpectrum of the ſilk was at firſt a dark green, and the ſpectrum of the white paper became of a pink. The ſpectra then both diſappeared; and then the internal ſpectrum was blue; and then, after a ſecond diſappearance, became yellow, and

and laſtly pink, whilſt the ſpectrum of the field varied into red and green.

Theſe ſucceſſions of different coloured ſpectra were not exactly the ſame in the different experiments, though obſerved, as near as could be, with the ſame quantity of light, and other ſimilar circumſtances; owing, I ſuppoſe, to trying too many experiments at a time; ſo that the eye was not quite free from the ſpectra of the colours which were previouſly attended to.

The alternate exertions of the retina in the preceding ſection, reſembled the oſcitation or pandiculation of the muſcles, as they were performed in directions contrary to each other, and were the conſequence of fatigue rather than of pain. And in this they differ from the ſucceſſive diſſimilar exertions of the retina, mentioned in this ſection, which reſemble in miniature the more violent agitations of the limbs in convulſive diſeaſes, as epilepſy, chorea S. Viti, and opiſthotonos; all which diſeaſes are perhaps, at firſt, the conſequence of pain, and have their periods afterwards eſtabliſhed by habit.

VIII. *The retina, after having been excited into action by a ſtimulus ſomewhat greater than the laſt mentioned, falls into a fixed ſpaſmodic action, which continues for ſome days.*

1. After having looked long at the meridian ſun, in making ſome of the preceding experiments, till the diſcs faded into a pale blue, I frequently obſerved a bright blue ſpectrum of the ſun on other objects all the next and the ſucceeding day, which conſtantly occurred when I attended to it, and frequently when I did not previouſly attend to it. When I cloſed and covered

my eyes, this appeared of a dull yellow; and at other times mixed with the colours of other objects on which it was thrown. It may be imagined, that this part of the retina was become insensible to white light, and thence a bluish spectrum became visible on all luminous objects; but as a yellowish spectrum was also seen in the closed and covered eye, there can remain no doubt of this being the spectrum of the sun. A similar appearance was observed by M. ÆPINUS, which he acknowledges he could give no account of. (Nov. Com. Petrop. V. 10, p. 2. and 6.)

The locked jaw, and some cataleptic spasms, are resembled by this phænomenon; and from hence we may learn the danger to the eye by inspecting very luminous objects too long a time.

IX. *A quantity of stimulus greater than the preceding induces a temporary paralysis of the organ of vision.*

1. Place a circular piece of bright red silk, about half an inch in diameter, on the middle of a sheet of white paper; lay them on the floor in a bright sunshine, and fixing your eyes steadily on the center of the red circle, for three or four minutes, at the distance of four or six feet from the object, the red silk will gradually become paler, and finally cease to appear red at all.

2. Similar to these are many other animal facts; as purges, opiates, and even poisons, and contagious matter, cease to stimulate our system, after we have been habituated to their use. So some people sleep undisturbed by a clock, or even by a forge hammer in their neighbourhood: and not only continued irritations, but violent exertions of any kind, are succeeded

by

by temporary paralyſis. The arm drops down after violent action, and continues for a time uſeleſs; and it is probable, that thoſe who have periſhed ſuddenly in ſwimming, or in ſcating on the ice, have owed their deaths to the paralyſis, or extreme fatigue, which ſucceeds every violent and continued exertion.

X. MISCELLANEOUS REMARKS.

There were ſome circumſtances occurred in making theſe experiments, which were liable to alter the reſults of them, and which I ſhall here mention for the aſſiſtance of others, who may wiſh to repeat them.

1. *Of direct and inverſe ſpectra exiſting at the ſame time; of reciprocal direct ſpectra; of a combination of direct and inverſe ſpectra; of a ſpectral halo; rules to pre-determine the colours of ſpectra.*

a. When an area, about ſix inches ſquare, of bright pink Indian paper, had been viewed on an area, about a foot ſquare, of white writing paper, the internal ſpectrum in the cloſed eye was green, being the reverſe ſpectrum of the pink paper; and the external ſpectrum was pink, being the direct ſpectrum of the pink paper. The ſame circumſtance happened when the internal area was white, and external one pink; that is, the internal ſpectrum was pink, and the external one green. All the ſame appearances occurred when the pink paper was laid on a black hat.

b. When ſix inches ſquare of deep violet poliſhed paper was viewed on a foot ſquare of white writing paper, the internal ſpectrum

ſpectrum was yellow, being the reverſe ſpectrum of the violet paper, and the external one was violet, being the direct ſpectrum of the violet paper.

c. When ſix inches ſquare of pink paper was viewed on a foot ſquare of blue paper, the internal ſpectrum was blue, and the external ſpectrum was pink; that is, the internal one was the direct ſpectrum of the external object, and the external one was the direct ſpectrum of the internal object, inſtead of their being each the reverſe ſpectrum of the objects they belonged to.

d. When ſix inches ſquare of blue paper were viewed on a foot ſquare of yellow paper, the interior ſpectrum became a brilliant yellow, and the exterior one a brilliant blue. The vivacity of the ſpectra was owing to their being excited both by the ſtimulus of the interior and exterior objects; ſo that the interior yellow ſpectrum was both the reverſe ſpectrum of the blue paper, and the direct one of the yellow paper; and the exterior blue ſpectrum was both the reverſe ſpectrum of the yellow paper, and the direct one of the blue paper.

e. When the internal area was only a ſquare half-inch of red paper, laid on a ſquare foot of dark violet paper, the internal ſpectrum was green, with a reddiſh-blue halo. When the red internal paper was two inches ſquare, the internal ſpectrum was a deeper green, and the external one redder. When the internal paper was ſix inches ſquare, the ſpectrum of it became blue, and the ſpectrum of the external paper was red.

f. When a ſquare half-inch of blue paper was laid on a ſix inch ſquare of yellow paper, the ſpectrum of the central paper in the cloſed eye was yellow, incircled with a blue halo. On looking long on the meridian ſun, the diſc fades into a pale blue ſurrounded with a whitiſh halo.

 The

These circumftances, though they very much perplexed the xperiments till they were inveftigated, admit of a fatisfactory xplanation; for while the rays from the bright internal ob-ect in exp. *a.* fall with their full force on the center of the etina, and, by fatiguing that part of it, induce the reverfe pectrum, many fcattered rays, from the fame internal pink paper, fall on the more external parts of the retina, but not in uch quantity as to occafion much fatigue, and hence induce he direct fpectrum of the pink colour in thofe parts of the ye. The fame reverfe and direct fpectra occur from the violet aper in exp. *b.*: and in exp. *c.* the fcattered rays from the entral pink paper produce a direct fpectrum of this colour on he external parts of the eye, while the fcattered rays from he external blue paper produce a direct fpectrum of that colour n the central part of the eye, inftead of thefe parts of the etina falling reciprocally into their reverfe fpectra. In exp. *d.* he colours being the reverfe of each other, the fcattered rays rom the exterior object falling on the central parts of the eye, nd there exciting their direct fpectrum, at the fame time that he retina was excited into a reverfe fpectrum by the central object, and this direct and reverfe fpectrum being of fimilar colour, the fuperior brilliancy of this fpectrum was produced. In exp. *e.* the effect of various quantities of ftimulus on the retina, from the different refpective fizes of the internal and external areas, induced a fpectrum of the internal area in the center of the eye, combined of the reverfe fpectrum of that in-ternal area and the direct one of the external area, in various fhades of colour, from a pale green to a deep blue, with fimi-lar changes in the fpectrum of the external area. For the fame reafons, when an internal bright object was fmall, as in exp. *f.* inftead of the whole of the fpectrum of the external object being

being reverfe to the colour of the internal object, only a kind of halo, or radiation of colour, fimilar to that of the internal object, was fpread a little way on the external fpectrum. For this internal blue area being fo fmall, the fcattered rays from it extended but a little way on the image of the external area of yellow paper, and could therefore produce only a blue halo round the yellow fpectrum in the center.

If any one fhould fufpect that the fcattered rays from the exterior coloured object do not intermix with the rays from the interior coloured object, and thus affect the central part of the eye, let him look through an opake tube, about two feet in length, and an inch in diameter, at a coloured wall of a room with one eye, and with the other eye naked; and he will find, that by fhutting out the lateral light, the area of the wall feen through a tube appears as if illuminated by the funfhine, compared with the other parts of it; from whence arifes the advantage of looking through a dark tube at diftant paintings.

Hence we may fafely deduce the following rules to determine before-hand the colours of all fpectra. 1. *The direct fpectrum* without any lateral light is an evanefcent reprefentation of its object in the unfatigued eye. 2. With fome lateral light it becomes of a colour combined of the direct fpectrum of the central object, and of the circumjacent objects, in proportion to their refpective quantity and brilliancy. 3. The *reverfe fpectrum* without lateral light is a reprefentation in the fatigued eye of the form of its objects, with fuch a colour as would be produced by all the primary colours, except that of the object. 4. With lateral light the colour is compounded of the reverfe fpectrum of the central object, and the direct fpectrum of the circumjacent objects, in proportion to their refpective quantity and brilliancy.

1. *Variation and vivacity of the ſpectra occaſioned by extraneous light.*

The reverſe ſpectrum, as has been before explained, is ſimi-ar to a colour, formed by a combination of all the primary olours, except that with which the eye has been fatigued in aking the experiment: ſo the reverſe ſpectrum of red is ſuch green as would be produced by a combination of all the other iſmatic colours. Now it muſt be obſerved, that this reverſe ectrum of red is therefore the direct ſpectrum of a combina-on of all the other priſmatic colours, except the red; whence, n removing the eye from a piece of red ſilk to a ſheet of hite paper, the green ſpectrum, which is perceived, may ther be called the reverſe ſpectrum of the red ſilk, or the rect ſpectrum of all the rays from the white paper, except e red; for in truth it is both. Hence we ſee the reaſon why is not eaſy to gain a direct ſpectrum of any coloured object the day-time, where there is much lateral light, except of ery bright objects, as of the ſetting ſun, or by looking rough an opake tube; becauſe the lateral external light lling alſo on the central part of the retina, contributes to duce the reverſe ſpectrum, which is at the ſame time the rect ſpectrum of that lateral light, deducting only the colour f the central object which we have been viewing. And for the me reaſon, it is difficult to gain the reverſe ſpectrum, where here is no lateral light to contribute to its formation. Thus, looking through an opake tube on a yellow wall, and cloſing y eye, without admitting any lateral light, the ſpectra were ll at firſt yellow; but at length changed into blue. And on oking in the ſame manner on red paper, I did at length get a green

green ſpectrum; but they were all at firſt red ones: and the ſame after looking at a candle in the night.

The reverſe ſpectrum was formed with greater facility when the eye was thrown from the object on a ſheet of white paper, or when light was admitted through the cloſed eyelids; becauſe not only the fatigued part of the retina was inclined ſpontaneouſly to fall into motions of a contrary direction; but being ſtill ſenſible to all other rays of light except that with which it was lately fatigued, was by theſe rays ſtimulated at the ſame time into thoſe motions which form the reverſe ſpectrum. Hence, when the reverſe ſpectrum of any colour became faint, it was wonderfully revived by admitting more light through the eyelids, by removing the hand from before them: and hence, on covering the cloſed eyelids, the ſpectrum would often ceaſe for a time, till the retina became ſenſible to the ſtimulus of the ſmaller quantity of light, and then it recurred. Nor was the ſpectrum only changed in vivacity, or in degree, by this admiſſion of light through the eyelids; but it frequently happened, after having viewed bright objects, that the ſpectrum in the cloſed and covered eye was changed into a third ſpectrum, when light was admitted through the eyelids: which third ſpectrum was compoſed of ſuch colours as could paſs through the eyelids, except thoſe of the object. Thus, when an area of half an inch diameter of pink paper was viewed on a ſheet of white paper in the ſunſhine, the ſpectrum with cloſed and covered eyes was green; but on removing the hands from before the cloſed eyelids, the ſpectrum became yellow, and returned inſtantly again to green, as often as the hands were applied to cover the eyelids, or removed from them: for the retina being now inſenſible to red light, the yellow rays paſſing through the eyelids in greater quantity than the other colours, induced a yellow ſpectrum; whereas if the

the ſpectrum was thrown on white paper, with the eyes open, it became only a lighter green.

Though a certain quantity of light facilitates the formation of the reverſe ſpectrum, a greater quantity prevents its formation, as the more powerful ſtimulus excites even the fatigued parts of the eye into action; otherwiſe we ſhould ſee the ſpectrum of the laſt viewed object as often as we turn our eyes. Hence the reverſe ſpectra are beſt ſeen by gradually approaching the hand near the cloſed eyelids to a certain diſtance only, which muſt be varied with the brightneſs of the day, or the energy of the ſpectrum. Add to this, that all dark ſpectra, as black, blue, or green, if light be admitted through the eyelids, after they have been ſome time covered, give reddiſh ſpectra, for the reaſons given in ſect. III. exp. 1.

From theſe circumſtances of the extraneous light coinciding with the ſpontaneous efforts of the fatigued retina to produce a reverſe ſpectrum, as was obſerved before, it is not eaſy to gain a direct ſpectrum, except of objects brighter than the ambient light; ſuch as a candle in the night, the ſetting ſun, or viewing a bright object through an opake tube; and then the reverſe ſpectrum is inſtantaneouſly produced by the admiſſion of ſome external light; and is as inſtantly converted again to the direct ſpectrum by the excluſion of it. Thus, on looking at the ſetting ſun, on cloſing the eyes, and covering them, a yellow ſpectrum is ſeen, which is the direct ſpectrum of the ſetting ſun; but on opening the eyes on the ſky, the yellow ſpectrum is immediately changed into a blue one, which is the reverſe ſpectrum of the yellow ſun, or the direct ſpectrum of the blue ſky, or a combination of both. And this is again transformed into a yellow one on cloſing the eyes, and ſo reciprocally, as quick as the motions of the opening and cloſing eyelids. Hence, when Mr. Melvill obſerved the ſcintillations of the ſtar Sirius to be ſometimes coloured, theſe were probably the direct ſpectrum of the blue ſky on the parts of the retina fatigued by the white light of the ſtar. (Eſſays Phyſical and Literary, p. 81. V. 2.)

When a direct ſpectrum is thrown on colours darker than itſelf, it mixes with them; as the yellow ſpectrum of the ſetting ſun, thrown on the green graſs, becomes a greener yellow. But when a direct ſpectrum is thrown on colours brighter than itſelf, it becomes inſtantly changed into the reverſe ſpectrum, which mixes with thoſe brighter colours. So the yellow ſpectrum of the ſetting ſun thrown on the luminous ſky becomes blue, and changes with the colour or brightneſs of the clouds on which it appears. But the reverſe ſpectrum mixes with every kind of colour on which it is thrown, whether brighter than itſelf or not: thus the reverſe ſpectrum, obtained by viewing a piece of yellow ſilk, when thrown on white paper was a lucid blue green; when thrown on black Turkey leather becomes a deep violet. And the ſpectrum of blue ſilk, thrown on white paper, was a light yellow; on black ſilk was an obſcure orange; and the blue ſpectrum, obtained from orange-coloured ſilk, thrown on yellow, became a green.

In theſe caſes the retina is thrown into activity or ſenſation by the ſtimulus of external colours, at the ſame time that it continues the activity or ſenſation which forms the ſpectra; in the ſame manner as the priſmatic colours, painted on a whirling top, are ſeen to mix together. When theſe colours of external objects are brighter than the direct ſpectrum which is thrown upon them, they change it into the reverſe ſpectrum, like the admiſſion of external light on a direct ſpectrum, as explained above. When they are darker than the direct ſpectrum,

:rum, they mix with it, their weaker ftimulus being infuffi-
:ient to induce the reverfe fpectrum.

III. *Variation of fpectra in refpect to number and figure and remiffion.*

When we look long and attentively at any object, the eye cannot always be kept intirely motionlefs; hence, on infpecting a circular area of red filk placed on white paper, a lucid crefcent or edge is feen to librate on one fide or other of the red circle: for the exterior parts of the retina fometimes falling on the edge of the central filk, and fometimes on the white paper, are lefs fatigued with red light than the central part of the retina, which is conftantly expofed to it; and therefore, when they fall on the edge of the red filk, they perceive it more vividly. Afterwards, when the eye becomes fatigued, a green fpectrum in the form of a crefcent is feen to librate on one fide or other of the central circle, as by the unfteadinefs of the eye a part of the fatigued retina falls on the white paper; and as by the increafing fatigue of the eye the central part of the filk appears paler, the edge on which the unfatigued part of the retina occafionally falls will appear of a deeper red than the original filk, becaufe it is compared with the pale internal part of it. M. de Buffon in making this experiment obferved, that the red edge of the filk was not only deeper coloured than the original filk; but, on his retreating a little from it, it became oblong, and at length divided into two, which muft have been owing to a change of the angle of the two optic axifes with the new diftance he obferved it at. Thus, if a pen is held up before a diftant candle, when we look intenfely at the pen two candles are feen behind it; when we look intenfely at the

the candle two pens are feen. If the fight be unfteady at the time of beholding the fun, even though one eye only be ufed, many images of the fun will appear, or luminous lines, when the eye is clofed. And as fome parts of thefe will be more vivid than others, and fome parts of them will be produced nearer the center of the eye than others, thefe will difappear fooner than the others; and hence the number and fhape of thefe fpectra of the fun will continually vary, as long as they exift. The caufe of fome being more vivid than others, is the unfteadinefs of the eye of the beholder, fo that fome parts of the retina have been longer expofed to the funbeams. That fome parts of a complicated fpectrum fade and return before other parts of it, the following experiment evinces. Draw three concentric circles; the external one an inch and a half in diameter, the middle one an inch, and the internal one half an inch; colour the external and internal areas blue, and the remaining one yellow, as in fig. 4.; after having looked about a minute on the center of thefe circles, in a bright light, the fpectrum of the external area appears firft in the clofed eye, then the middle area, and laftly the central one; and then the central one difappears, and the others in inverted order. If concentric circles of more colours are added, it produces the beautiful ever changing fpectrum in fect. I. exp. 2.

From hence it would feem, that the center of the eye produces quicker remiffions of fpectra, owing perhaps to its greater fenfibility; that is, to its more energetic exertions. Thefe remiffions of fpectra bear fome analogy to the tremors of the hands, and palpitations of the heart, of weak people: and perhaps a criterion of the ftrength of any mufcle or nerve may be taken from the time it can be continued in exertion.

IV. *Variation of spectra in respect to brilliancy; the visibility of the circulation of the blood in the eye.*

1. The meridian or evening light makes a difference in the colours of some spectra; for as the sun descends, the red rays, which are less refrangible by the convex atmosphere, abound in great quantity. Whence the spectrum of the light parts of a window at this time, or early in the morning, is red; and becomes blue either a little later or earlier; and white in the meridian day; and is also variable from the colour of the clouds or sky which are opposed to the window.

2. All these experiments are liable to be confounded, if they are made too soon after each other, as the remaining spectrum will mix with the new ones. This is a very troublesome circumstance to painters, who are obliged to look long upon the same colour; and in particular to those whose eyes, from natural debility, cannot long continue the same kind of exertion. For the same reason, in making these experiments, the result becomes much varied if the eyes, after viewing any object, are removed on other objects for but an instant of time, before we close them to view the spectrum; for the light from the object, of which we had only a transient view, in the very time of closing our eyes acts as a stimulus on the fatigued retina; and for a time prevents the desired spectrum from appearing, or mixes its own spectrum with it. Whence, after the eyelids are closed, either a dark field, or some unexpected colours, are beheld for a few seconds, before the desired spectrum becomes distinctly visible.

3. The length of time taken up in viewing an object, of which we are to observe the spectrum, makes a great difference in

in the appearance of the fpectrum, not only in its vivacity, but in its colour; as the direct fpectrum of the central object, or of the circumjacent ones, and alfo the reverfe fpectra of both, with their various combinations, as well as the time of their duration in the eye, and of their remiffions or alternations, depend upon the degree of fatigue the retina is fubjected to. The Chevalier D'ARCY conftructed a machine by which a coal of fire was whirled round in the dark, and found, that when a luminous body made a revolution in eight thirds of time, it prefented to the eye a complete circle of fire; from whence he concludes, that the impreffion continues on the organ about the feventh part of a fecond. (Mém. de l'Acad. des Sc. 1765.) This, however, is only to be confidered as the fhorteft time of the duration of thefe direct fpectra; fince in the fatigued eye both the direct and reverfe fpectra, with their intermiffions, appear to take up many feconds of time, and feem very variable in proportion to the circumftances of fatigue or energy.

4. It fometimes happens, if the eyeballs have been rubbed hard with the fingers, that lucid fparks are feen in quick motion amidft the fpectrum we are attending to. This is fimilar to the flafhes of fire from a ftroke on the eye in fighting, and is refembled by the warmth and glow which appear upon the fkin after friction, and is probably owing to an acceleration of the arterial blood into the veffels emptied by the previous preffure. By being accuftomed to obferve fuch fmall fenfations in the eye, it is eafy to fee the circulation of the blood in this organ. I have attended to this frequently, when I have obferved my eyes more than commonly fenfible to other fpectra. The circulation may be feen either in both eyes at a time, or only in one of them; for as a certain quantity of light is neceffary to

o produce this curious phænomenon, if one hand be brought nearer the closed eyelids than the other, the circulation in that eye will for a time disappear. For the easier viewing the circulation, it is sometimes necessary to rub the eyes with a certain degree of force after they are closed, and to hold the breath rather longer than is agreeable, which, by accumulating more blood in the eye, facilitates the experiment; but in general it may be seen distinctly after having examined other spectra with your back to the light, till the eyes become weary; then having covered your closed eyelids for half a minute, till the spectrum is faded away which you were examining, turn your face to the light, and removing your hands from the eyelids, by and by again shade them a little, and the circulation becomes curiously distinct. The streams of blood are however generally seen to unite, which shews it to be the venous circulation, owing, I suppose, to the greater opacity of the colour of the blood in these vessels; for this venous circulation is also much more easily seen by the microscope in the tail of a tadpole.

V. Variation of spectra in respect to distinctness and size; with a new way of magnifying objects.

1. It was before observed, that when the two colours viewed together were opposite to each other, as yellow and blue, red and green, &c. according to the table of reflections and transmissions of light in Sir Isaac Newton's Optics, B. II. fig. 3. the spectra of those colours were of all others the most brilliant, and best defined; because they were combined of the reverse spectrum of one colour, and of the direct spectrum of the other. Hence, in books printed with small types, or in

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the minute graduation of thermometers, or of clock-faces, which are to be ſeen at a diſtance, if the letters or figures are coloured with orange, and the ground with indigo; or the letters with red, and the ground with green; or any other lucid colour is uſed for the letters, the ſpectrum of which is ſimilar to the colour of the ground; ſuch letters will be ſeen much more diſtinctly, and with leſs confuſion, than in black or white: for as the ſpectrum of the letter is the ſame colour with the ground on which they are ſeen, the unſteadineſs of the eye in long attending to them will not produce coloured lines by the edges of the letters, which is the principal cauſe of their confuſion. The beauty of colours lying in vicinity to each other, whoſe ſpectra are thus reciprocally ſimilar to each colour, is owing to this greater eaſe that the eye experiences in beholding them diſtinctly; and it is probable, in the organ of hearing a ſimilar circumſtance may conſtitute the pleaſure of melody. Sir ISAAC NEWTON obſerves, that gold and indigo were agreeable when viewed together; and thinks there may be ſome analogy between the ſenſations of light and ſound. (Optics, Qu. 14.)

In viewing the ſpectra of bright objects, as of an area of red ſilk of half an inch diameter on white paper, it is eaſy to magnify it to tenfold its ſize: for if, when the ſpectrum is formed, you ſtill keep your eye fixed on the ſilk area, and remove it a few inches further from you, a green circle is ſeen round the red ſilk: for the angle now ſubtended by the ſilk is leſs than it was when the ſpectrum was formed, but that of the ſpectrum continues the ſame, and our imagination places them at the ſame diſtance. Thus when you view a ſpectrum on a ſheet of white paper, if you approach the paper to the eye, you may diminiſh it to a point; and if the paper is made to recede from the

the eye, the ſpectrum will appear magnified in proportion to the diſtance.

I was ſurpriſed, and agreeably amuſed, with the following experiment. I covered a paper about four inches ſquare with yellow, and with a pen filled with a blue colour wrote upon the middle of it the word BANKS in capitals, as in fig. 5. and, ſitting with my back to the ſun, fixed my eyes for a minute exactly on the center of the letter N in the middle of the word; after cloſing my eyes, and ſhading them ſomewhat with my hand, the word was diſtinctly ſeen in the ſpectrum in yellow letters on a blue field; and then, on opening my eyes on a yellowiſh wall at twenty feet diſtance, the magnified name of BANKS appeared written on the wall in golden characters.

CONCLUSION.

It was obſerved by the learned M. SAUVAGES (Noſol. method. Cl. VIII. Ord. 1.) that the pulſations of the optic artery might be perceived by looking attentively on a white wall well illuminated. A kind of net-work, darker than the other parts of the wall, appears and vaniſhes alternately with every pulſation. This change of the colour of the wall he well aſcribes to the compreſſion of the retina by the diaſtole of the artery. The various colours produced in the eye by the preſſure of the finger, or by a ſtroke on it, as mentioned by Sir ISAAC NEWTON, ſeem likewiſe to originate from the unequal preſſure on various parts of the retina. Now as Sir ISAAC NEWTON has ſhewn, that all the different colours are reflected or tranſmitted by the laminæ of ſoap bubbles, or of air, according to their different thickneſs or thinneſs, is it not probable, that the effect

effect of the activity of the retina may be to alter its thickneſs or thinneſs, ſo as better to adapt it to reflect or tranſmit the colours which ſtimulate it into action? May not muſcular fibres exiſt in the retina for this purpoſe, which may be leſs minute than the locomotive muſcles of microſcopic animals? May not theſe muſcular actions of the retina conſtitute the ſenſation of lights and colours; and the voluntary repetitions of them, when the object is withdrawn, conſtitute our memory of them? And laſtly, may not the laws of the ſenſations of light, here inveſtigated, be applicable to all our other ſenſes, and much contribute to elucidate many phænomena of animal bodies both in their healthy and diſeaſed ſtate; and thus render this inveſtigation well worthy the attention of the phyſician, the metaphyſician, and the natural philoſopher?

Derby, November 1, 1785.

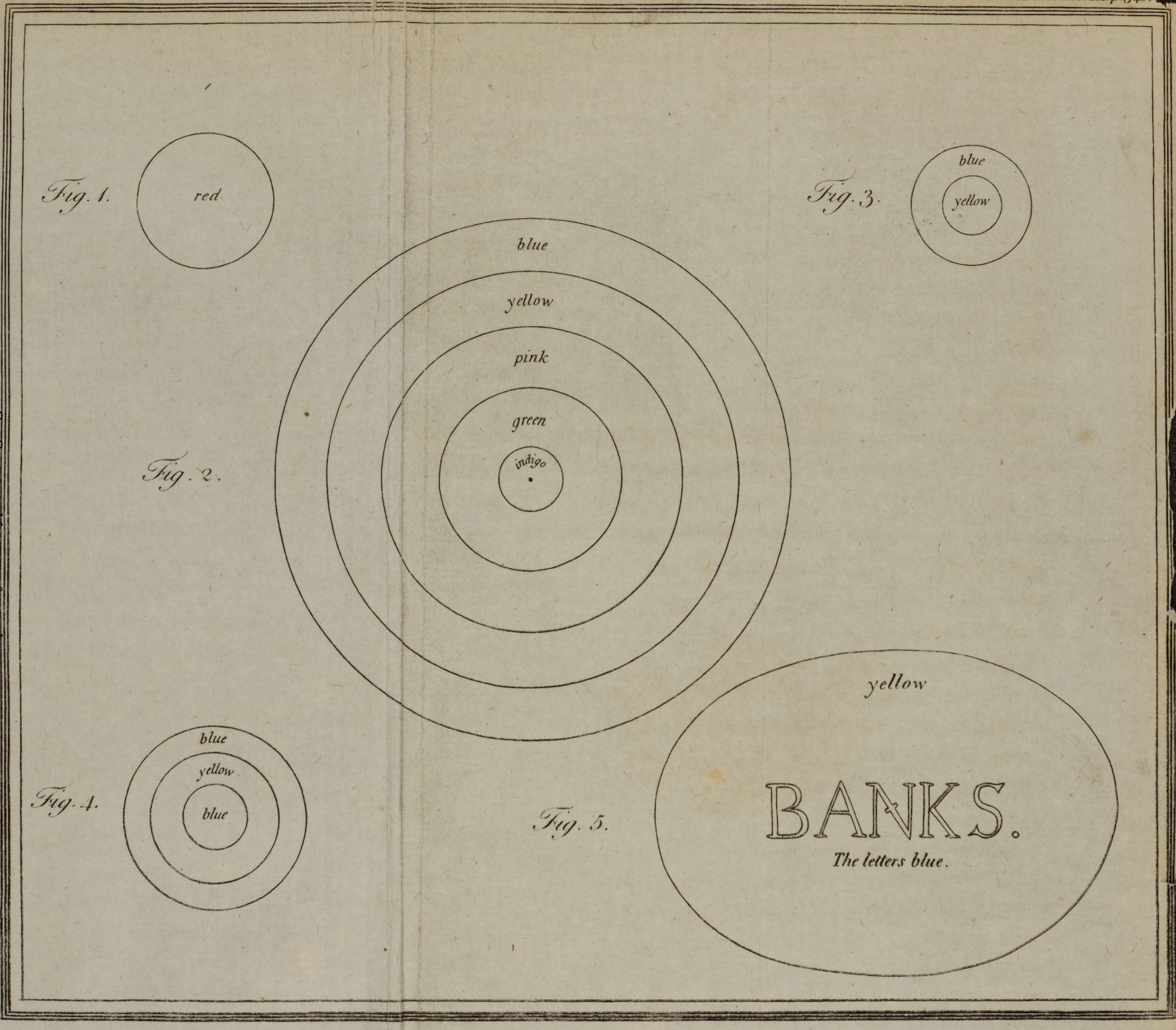
Fig. 1.
red
Fig. 2.
blue
yellow
pink
green
indigo
Fig. 3.
blue
yellow
Fig. 4.
blue
yellow
blue
Fig. 5.
yellow
BANKS.
The letters blue.